Precision Tests of Lattice QCD

Lattice QCD is the only rigorous method for calculating the properties of the strong interactions.

Understanding calculational accuracies is an essential part of the lattice program.

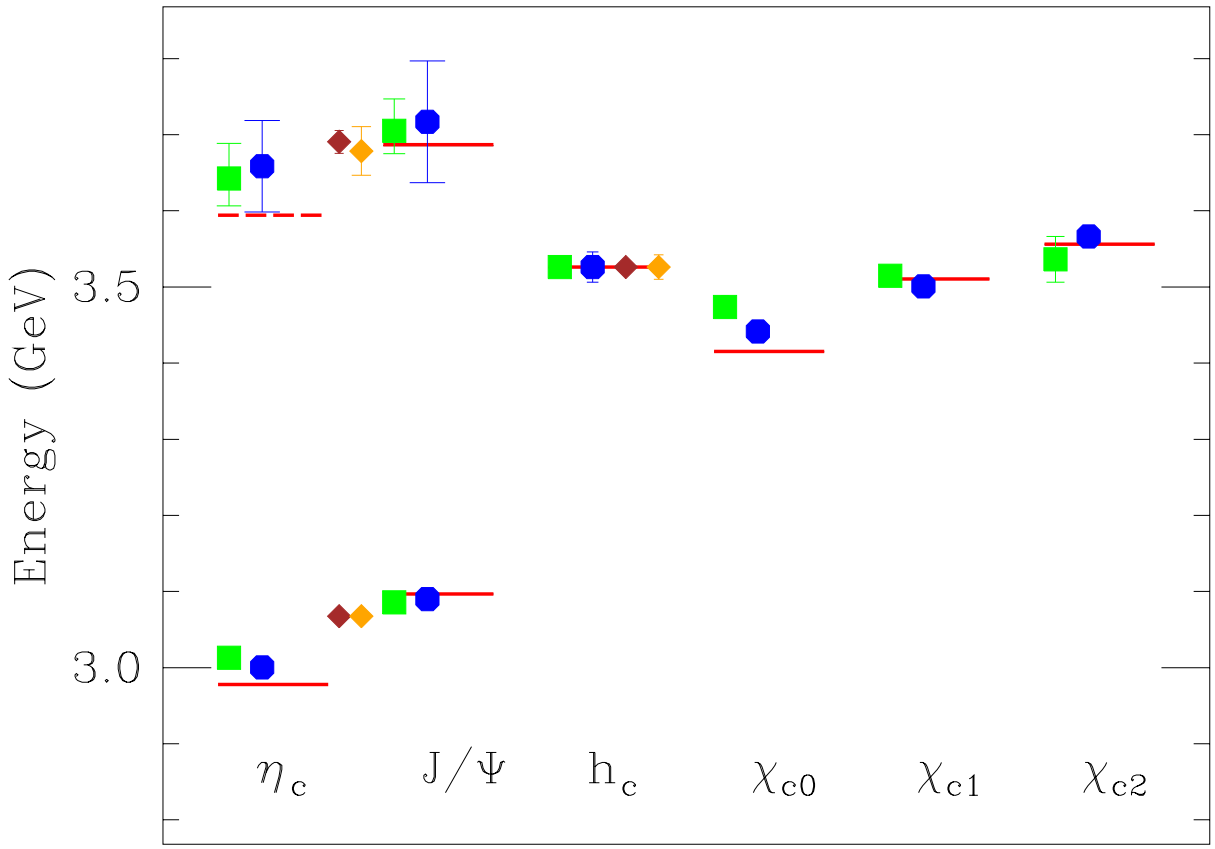
Quarkonia, heavy quark-antiquark states ($c\overline{c}$, "charmonium", $b\overline{b}$, "bottomonium") provide a good test problem.

Quark velocities are small: $(v_q/c)^2 \sim (\Lambda_{\rm QCD}/m_q)^2 << 1$.
Nonrelativistic methods allow improved understanding of and control over uncertainties: quenching, a, V, excited states, ...

This provides:

- Test of error analysis used in more typical harder cases (light quarks).
- Best outputs of some important quantities:
  α_s, m_b, m_c.

Spectrum of $c\bar{c}$ mesons (J/ψ, ψ', etc.)



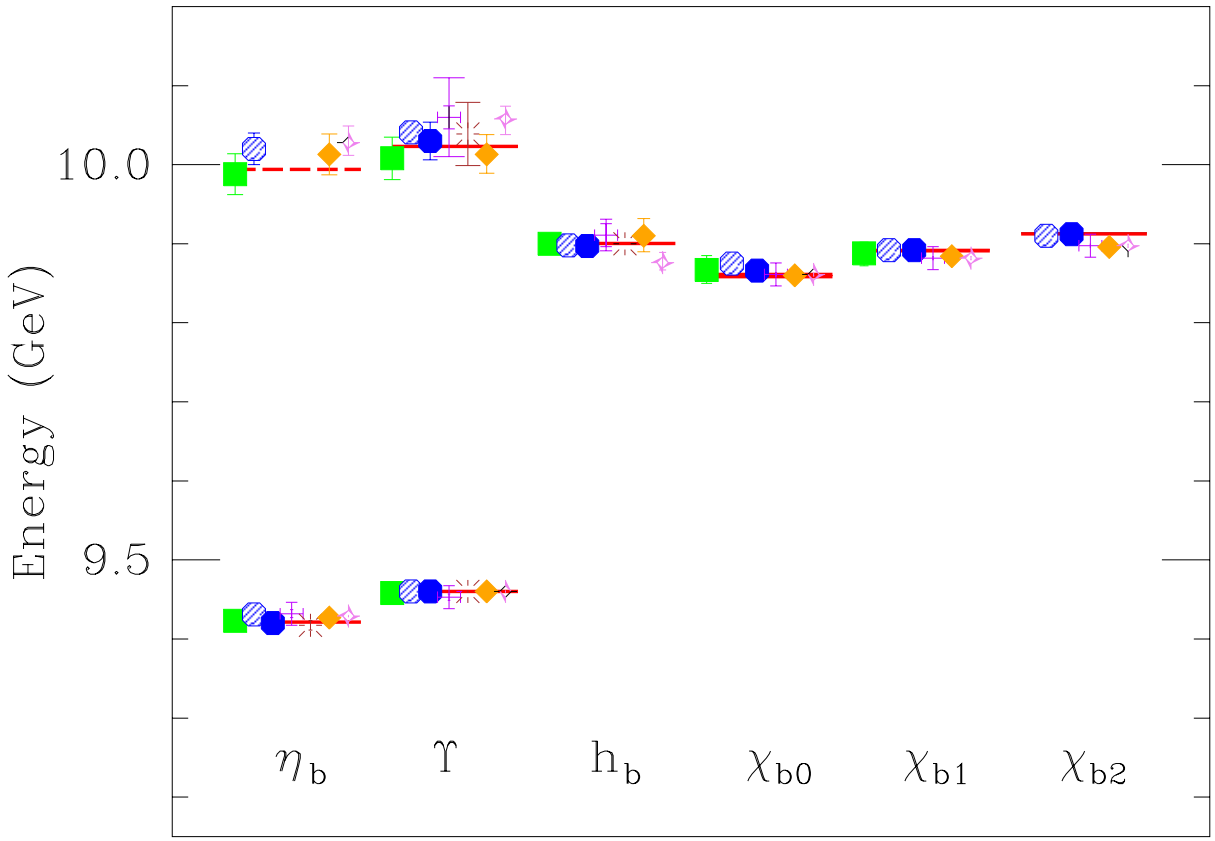
El-Khadra review, 1998

Spectrum agrees with experiment to within expected error.

Spin splittings are sensitive to errors, and useful for testing uncertainty analysis.

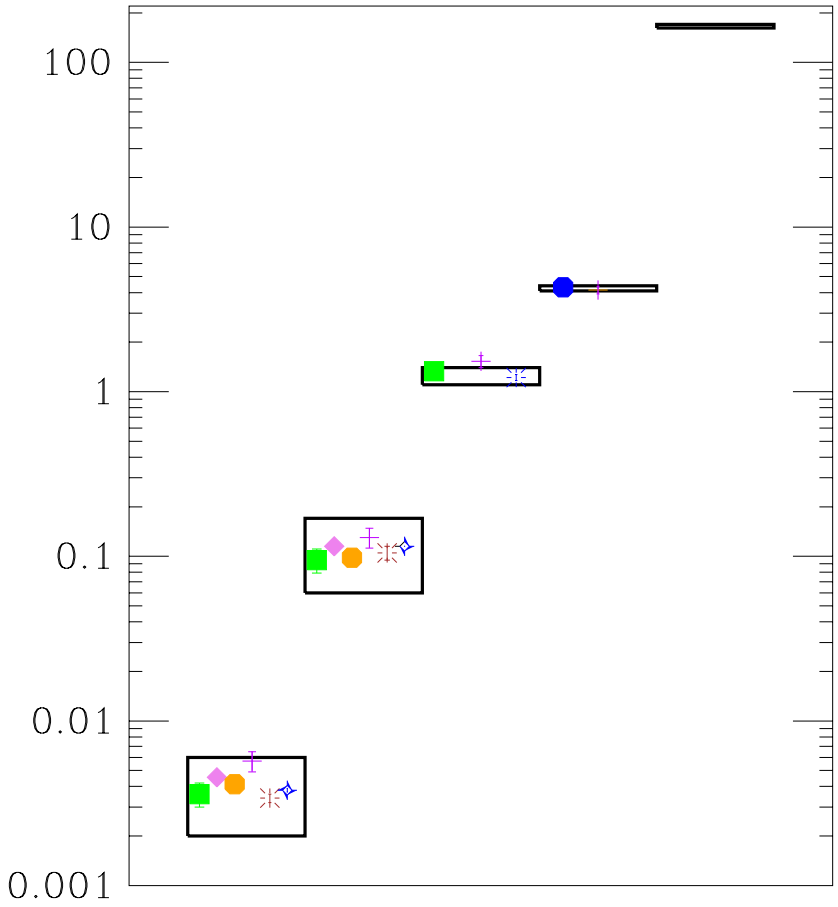
Spin independent levels (e.g., $(M_\psi + 3M_{\eta_c})/4$, M_{h_c}) are insensitive to errors, useful for extracting m_c, α_s.

Spectrum of $b\bar{b}$ mesons (Υ, Υ', etc.)



El-Khadra review, 1998

Quark Masses



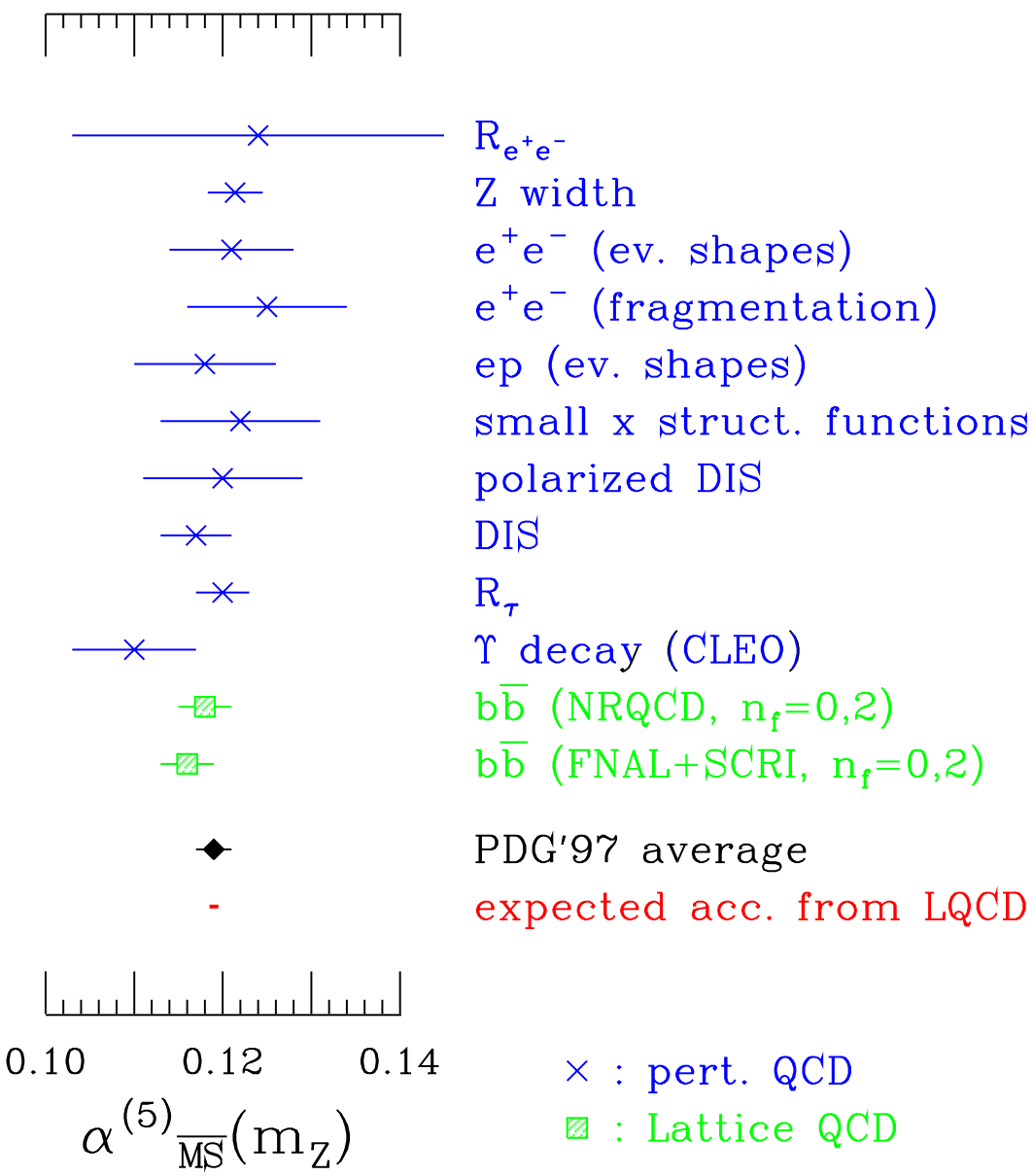
El-Khadra review, 1998

Lattice results for: $(m_u + m_d)/2$, m_s, m_c, and m_b, along with the Tevatron result for m_t. (In GeV.)

The quark masses, m_q, and the strong coupling constant, α_s, are *fundamental parameters of the standard model*, undetermined by current theory. They are required for analyzing QCD expermiment and for testing speculative theories of physics beyond the standard model.

Lattice QCD provides the only rigorous determination of the light quark masses m_u, m_d, and m_s. It provides the most accurate determinations of m_c and m_b.

The Strong Coupling Constant



Particle Data Group, 1997; Shigemitsu review, 1997

Current lattice uncertainties (few %) dominated by quenching, perturbation theory. Unquenched calculations and third order of perturbation theory bring expected uncertainty to 0.5%.